HOVERING CRAFT & HYDROFOIL

THE INTERNATIONAL REVIEW OF AIR CUSHION VEHICLES AND HYDROFOILS

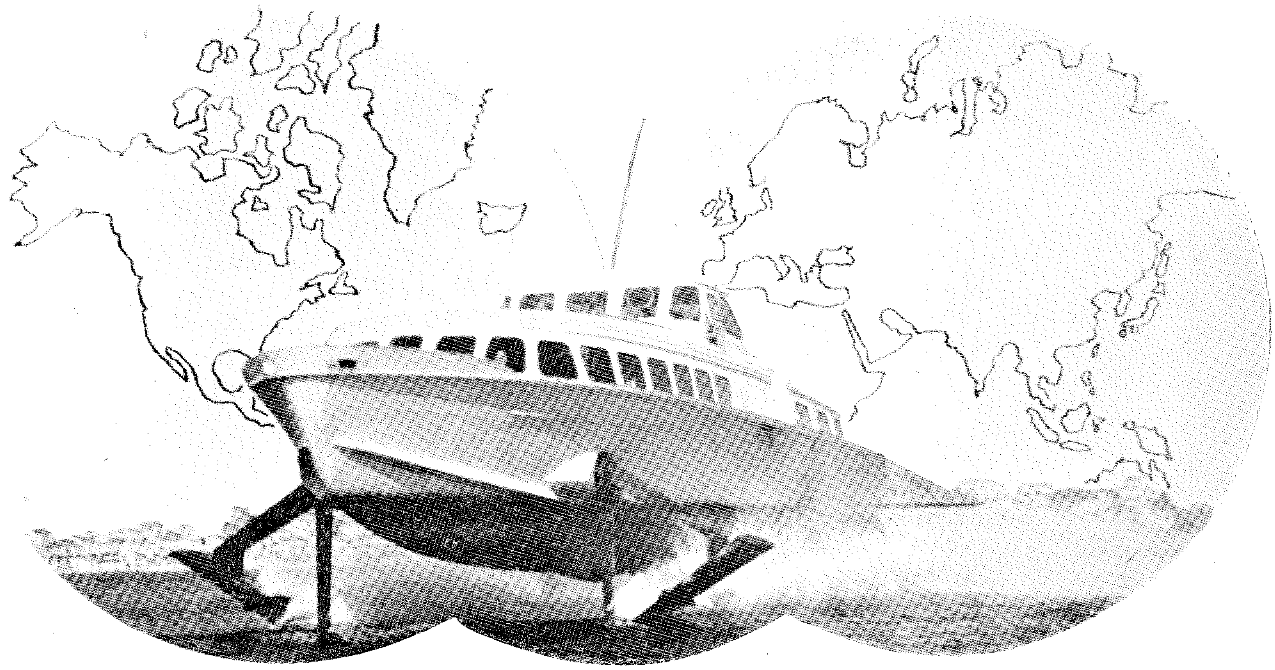
Volume 2 Number 4

JANUARY 1963

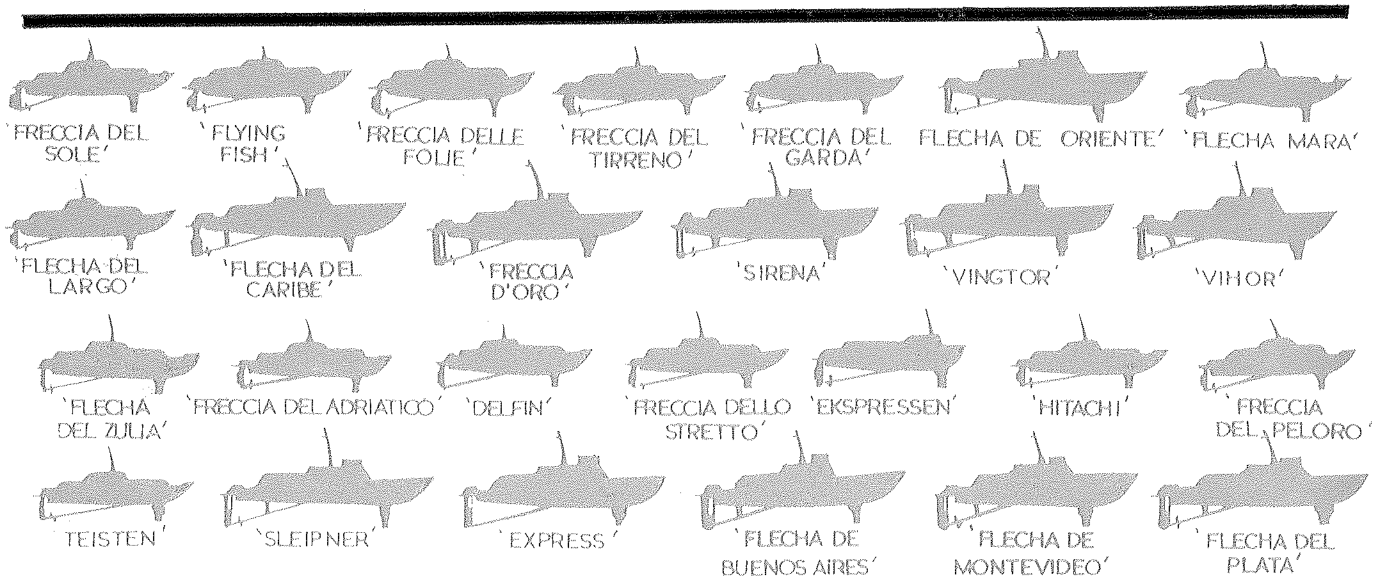
KALERGHI - McLEAVY PUBLICATIONS

Cantiere Navale RODRIQUEZ

MESSINA (Italy)



The greatest experience in the world in the construction of hydrofoil boats



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HOVERING CRAFT & HYDROFOIL

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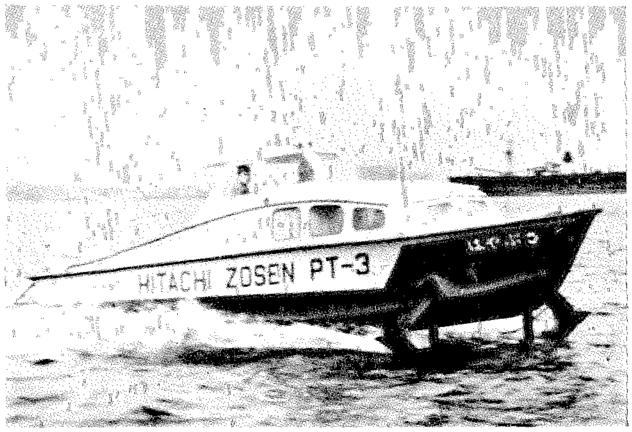
First Hovering Craft & Hydrofoil Monthly in the World



Supramar PT 3 hydrofoils similar to this Hitachi-built craft are in service in six different countries. A report on their work with waterpolice on the Rhine appears on pages 22 and 23 of this issue

HYDROFOILS – ANOTHER YEAR OF PROGRESS

SINCE January last the number of hydrofoil manufacturers in the world has almost trebled — and there is every likelihood that the industry will continue to grow in 1963.

The arguments for the hydrofoil are as strong as ever and if its critics are nowadays more subdued it is because they have at last bothered to get themselves informed. Even the most conservative of official maritime agencies are beginning to recognise the particular qualities of the craft, and their broadening view alone is everywhere an encouragement to manufacturers and potential operators.

This year is of great significance to both as it will see the introduction of at least a dozen new designs — civil and military — and the opening of a score of new services in North and South America, Europe, Scandinavia, the Mediterranean and the Far East. In the U.S.A. interest will focus firstly on the service to be operated this spring by the Denison between Port Everglades and the Bahamas, the longest scheduled open sea passage ever to be undertaken by a hydrofoil; and secondly, on the trials of the Boeing PC(H).

In Europe there is tremendous interest in the Supramar PT 90 — the 200-seat "fourth generation" craft designed by that redoubtable pioneer Baron Hans von Schertel. Details are to be announced shortly.

To the list of Japanese hydrofoil manufacturers can now be added the name Ishikawajima Harima Heavy Industries Ltd., whose first craft successfully completed its trials recently. Russia's interest in ocean-going foilborne craft is likely to be shown in 1963 by the appearance of a new series of experimental hydrofoils, possibly along the lines of the Aquacraft which we illustrated in our December issue.

In many ways the new hydrofoil year promises to be an exciting one — one that will bring further technological progress and further recognition to this fast-yet-economical mode of over-water transportation.

IN THIS ISSUE

COVER PICTURE : *The Vickers VA-2 was recently tested by the Joint Services Hovercraft Development Unit at Lee-on-Solent. On arrival the craft climbed a slipway with a gradient of 1 in 11, crossed a road and traversed the airfield perimeter track between parked cars. A report appears on page 5*

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Joint Editors:

JUANITA KALERGHI ROY McLEAVY

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The Westland SR.N2 operating over pack ice up to 9 in. thick and floes 6 ft. long in Wootton Creek, Isle of Wight. Icing tests at sub-zero water and air temperatures showed that the craft's operation at normal speeds and hovering heights was unimpaired and its fundamental mechanisms were unaffected

People and Projects

On January 15th the **Westland SR.N2** completed a 50-mile trip around the Isle of Wight in 51 minutes 51 seconds — an improvement of twenty minutes over the last trip, made in August 1962.

Although the engines are still underrated a top speed of 65 knots (75 mph) was attained and the average speed was 58 knots (67 mph). The wind was fairly calm and the wave height was 9 in. to 1 ft. Twenty passengers were carried.

★ ★ ★

The **Royal Canadian Navy** has been given authority by the Canadian Government to start the construction of a prototype 200-ton hydrofoil for anti-submarine warfare.

De Havilland Aircraft, Downsview, Ontario, recently completed a $260,000 hydrofoil feasibility study for the Canadian Defence Department. The Defence Research Board has been investigating the potential of hydrofoils for the past twelve years.

★ ★ ★

An **Aquavion Waterman** has been purchased as a ship's launch for the new Ben Line cargo liner Benarty, due to leave London early this year on her maiden voyage to Asia.

Another Waterman has been bought by the Bombay Burma Trading Corporation for use on its Borneo timber plantation.

☆ ☆ ☆

An American company, **National Patent Development Corporation,** of Park Avenue, New York, has secured the rights to licence the manufacture of Russian hydrofoils in the USA.

The craft covered by the licence arrangements are the 66-seat Raketa (Rocket); the 150-seat Meteor and the six-passenger Molnia (Lightning) runabout.

This is the first cross-licensing agreement on patents and technology between the Soviet Union and the USA, recognition *de facto* of the United States Patent System being secured for the first time from Soviet officials. One of the members of the NPDC Board is Lord Malcolm Douglas Hamilton, O.B.E., D.F.C., a former member of the British House of Commons and former Assistant to the President of Philco International Corporation.

The **Ford Motor Company's Aeronutronic Division** has completed a design study for an air cushion vehicle for long distance cargo and passenger services. A series of small fans along each side of the craft would provide lift in a similar manner to the arrangement on the ACV-1. Two fin-mounted gas turbine engines driving shrouded airscrews would propel the craft.

★ ★ ★

Britain's Minister of Transport, Mr. Marples, is studying detailed plans of the Hover-Train which may link all Britain's large business centres — London, Bristol, Birmingham, Manchester and Glasgow — by straight shallow concrete troughs, and B.R. officials are going to be invited to test this during the summer. **Christopher Cockerell** and his team of engineers are at work at Hythe, Hants, on the Hover-Train concept.

Mr. Cockerell maintains that the British transport system is wasteful and the frictionless air cushion is a much better bet for people wishing to travel long distances. Each Hover-Train will consist of a carriage with seats for 500 passengers shaped like an airplane fuselage and weighing 50 tons. Larger types could be built to carry cars or lorries.

Civil engineers have investigated the cost and it is believed that it could be done as cheaply as laying and operating a railway line and certainly more cheaply than air or helicopter travel. Passengers would not be obliged to keep on changing or worry about weather conditions.

★ ★ ★

The first ever trials of a hovercraft over snow and ice have been completed by the latest Vickers machine, the VA-2, at the **Joint Services Hovercraft Development Unit** at Lee-on-Solent.

VA-2 completed the journey down Southampton Water between Vickers Works at Itchen and the beach at Lee-on-Solent, a distance of 14 miles, at a speed of 45 knots. On arrival it undertook the transition from water on to the Royal Naval Air Station under its own power.

This manoeuvre involved climbing a slipway with a gradient of 1 in 11, crossing a road and running along the airfield perimeter track between parked cars — a feat that was aided by the 2-wheel retractable undercarriage which has been fitted to VA-2 to assist control at slow speeds.

The exercise was primarily undertaken to test the effects of snow and ice in restricting the driver's vision and increasing vehicle weight if blown on to the craft's structure, to examine the control problems likely to be caused by undulations and unevenness of the snow surface, and to assess the extent of engine and frame icing that may be expected to occur when operating in cold climates. Six runs were made successfully over packed snow and ice which varied in depth from 3 to 6 inches with drifts of up to 1½ feet, but since the snow had been sealed by a layer of ice, no spray was encountered and temperatures were not low enough to enable the effect of icing on the craft to be assessed.

The control problems proved to be the same as those associated with normal overland operation, namely the tendency for the craft to drift sideways over uneven surfaces.

Overall, the trials confirmed the designers' assertion that pure hovercraft can operate over snow and ice covered surfaces in conditions which are impossible for conventional vehicles This is an important factor in opening up areas similar to those found in Northern Canada in winter time.

The Vickers VA-2 is a five-seat craft which has been specially developed for overseas demonstration. It is powered by three Rolls-Royce Continental engines for lift and propulsion and has a range of 75 miles at a cruising speed of 40 knots, with a 60 knot maximum.

Details of its tour programme for 1963 are expected to be issued very soon.

★ ★ ★

Since our note last month on the inflatable air cushion vehicle model of **Thomas Weilenmann** of Gothenburg, Sweden, further information is available.

As can be discerned from the accompanying photographs the experimental model is an extremely simplified one and is therefore not giving a very high efficiency. Although all-up starting weight is as high as 1.65 pounds, a 1.5 cc Diesel engine is adequate for obtaining full hovering effect.

The model is at present being modified and fitted with an airscrew propelling arrangement and we understand that a further more advanced model of quite a different design is under construction.

Thomas Weilenmann suggests that inflatable air cushion vehicles would lend themselves to military, scientific, commercial applications, and for the rescue of drowning persons. In addition they could ultimately prove to be the week-end vehicle for Mr. Everyman.

★ ★ ★

A new hovercraft is to be built this Spring by the firm of **J. Samuel White** of Cowes. The project has been sponsored by Hovercraft Development Ltd.

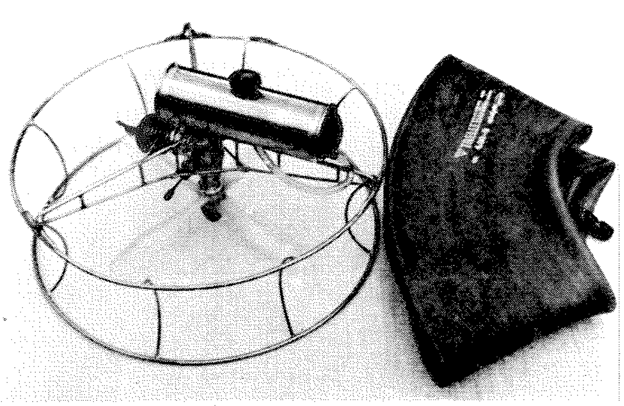
The HD-1 is intended for purely research purposes and will be used primarily for developing and testing various systems for improving the efficiency and control of hovercraft. Some of the early trials are likely to be devoted to the testing of flexible extensions to the solid hull structure. The craft will have a hull built by conventional boat-building methods from timber and marine plywood.

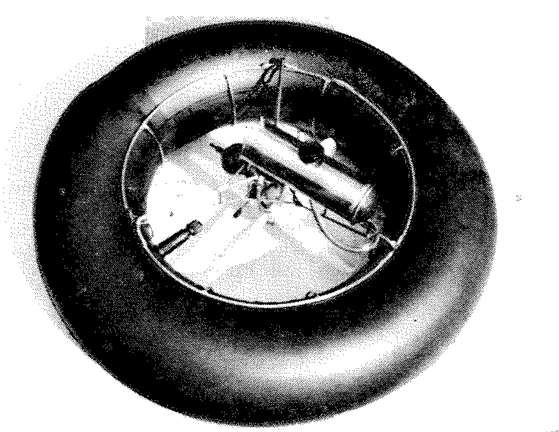
The overall length of the craft is 50 feet; the overall beam 17 feet; all-up weight 5½ tons; design cruising speed of 25 knots. Lift is provided by two Coventry Climax engines and propulsion by two airscrews driven by Rolls Royce Continental aero engines.

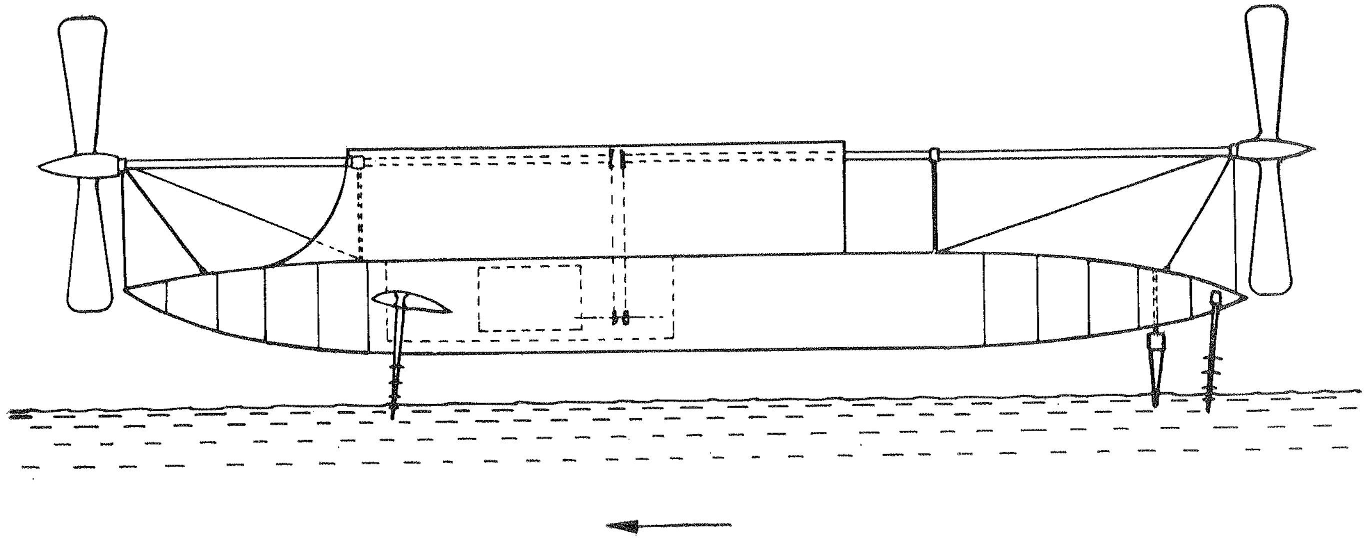
★ ★ ★

Sea Legs, the US Navy hydrofoil operated by **Gibbs & Cox Inc.,** New York, holds the record for having travelled further than any other craft with fully-submerged auto-stabilized foils. The record claimed is 6,700 stat. miles officially logged on her foils in all waters from New London, Conn., to Washington, D.C. Sea Legs is still operational on an experimental basis.

This model inflatable air cushion vehicle has been built by Thomas Weilenmann of Gothenburg, Sweden, to demonstrate how such craft would lend themselves for rescue, military, commercial and scientific applications. Details are given in a news report above







The Hydro-Aeroplane Boats of Enrico Forlanini

George Zangakis

ENRICO FORLANINI, the famous Italian engineer, born December 13th, 1848, died October 9th, 1930, was a man of many interests. In 1885 he built an aeroplane model which took off, by means of a gunpowder tube, along two steel wires. It is recorded that the model reached a height of 600 ft. in twenty to twenty-five seconds. The original model was exhibited at The Olympia International Aero Exhibition, July 16th-27th, 1929.

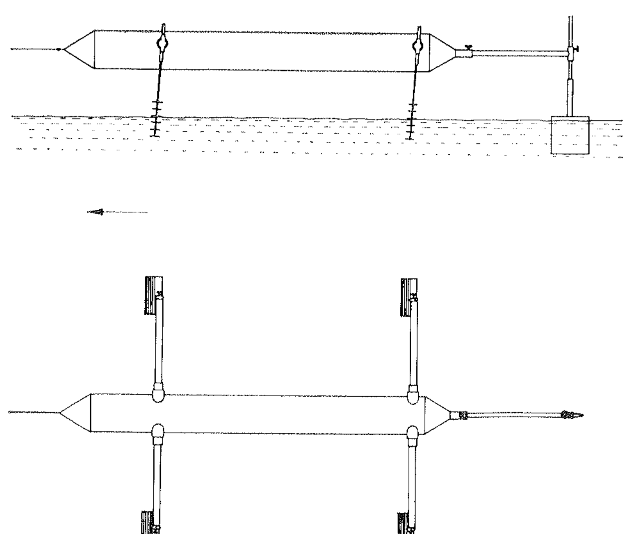
The first helicopter with an engine to leave the ground was designed and built by Forlanini. The machine had two-bladed rotors mounted one above the other. The upper rotor was free to rotate but the lower one was rigidly attached to the fuselage so that the complete machine revolved. It is recorded that the model used a one-fifth horse power steam engine weighing approximately seven and a half pounds to turn the upper rotor. Many flights were made and Forlanini claimed that on June 29th, 1877, his model rose to a height of forty feet and made flights of forty seconds duration. This model was also exhibited at Olympia in 1929.

During the period 1905-1914 Forlanini designed and built a number of semi-rigid airships. Three were ordered by the British Government, but due to the outbreak of the 1914-1918 war they were never delivered. Forlanini also interested himself in hydrofoil machines or to use his own description Hydro-aeroplane boats. His interest appears to have started in 1898 and tests of his hydrovaned boat were completed during 1905. It is known that a model of the craft shown in Fig. 1, weighing approximately eleven pounds, was built and tested experimentally.

The main cylindrical body, formed from sheet material, was closed at both ends by conical caps. Laterally extending tubular arms screwed into threaded sockets on the main body, till locked in position by setscrews. The outer part of each arm was provided with sockets to house vertical rods supporting a number of slightly concave foils. The sockets permitted the rods to be moved through a small angle, and locked in the position desired by set screws. A rear extension bar carried a variable position rudder.

The model was towed at speeds varying between 200 and 600 feet per minute, and the height of the main body above the surface of the water varied between three and six inches according to the speed of travel. Resistance of the model, measured by the tension of the towing rope not exceeding

Figure 1. *Forlanini's first model*



SR.N2 Progress

The 27-ton, 76-seat Westland SR.N2—the world's biggest air cushion vehicle —has to date carried 3,700 passengers and covered some 3,500 miles during development trials. A speed of 73 knots has been reached and the craft has repeatedly operated in 4 to 5 ft. seas.

A 74% regularity was achieved during an experimental scheduled passenger service between Ryde, Isle of Wight and Southsea during the second phase of the trials. The majority of the cancellations were due solely to the sea state being outside the officially-approved operating limits for the service. Despite rough weather—Force 4 to 7 winds, steep short seas, and waves up to 4 ft.—passengers were most impressed by the smoothness of the ride, due primarily to the craft's Westland-patented flexible rubber 'skirt'. Cruising speeds as high as 53 knots were achieved, and turnround times cut to as little as 3 minutes with full passenger loads.

A 'strip' examination after 150 hours' operation showed the craft's transmission system to be barely "run in", virtually no sign of corrosion and only minor structural damage such as skin dents.

WESTLAND the first name in ACV'S (air cushion vehicles)

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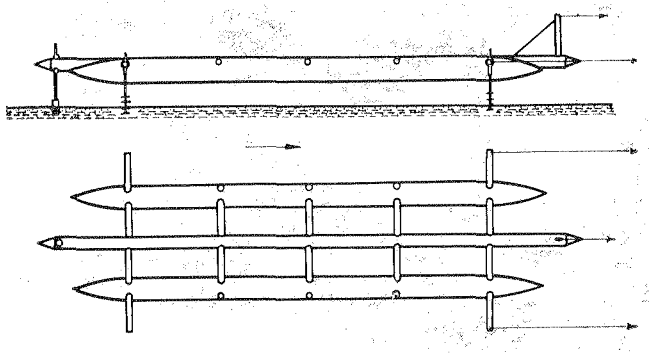


Figure 2. *Forlanini's second model*

approximately one pound and a half, was one-seventh the total weight of the model.

Fig. 2 illustrates the next experimental stage.

Three tubes connected together by cross bars carried foil attachments in a similar manner to that shown in Fig. 1. Experiments made by towing this craft at speeds varying between five and seven metres per second enabled Forlanini to arrive at the following approximate formulae for constructing a practical and operative craft.

$$P = (12 + 425X - 1250X^2)\ AV^2$$

and $$S = (1.20 + 100x^2)\ AV^2$$

From these formulae, differentiating, it results that the maximal ratio $\frac{P}{S}$ is obtained when $X = 0.063$, which Forlanini stated was confirmed very well in practice.

Using this value the formula gives

$$P = 34AV^2$$
$$S = 1.6AV^2$$

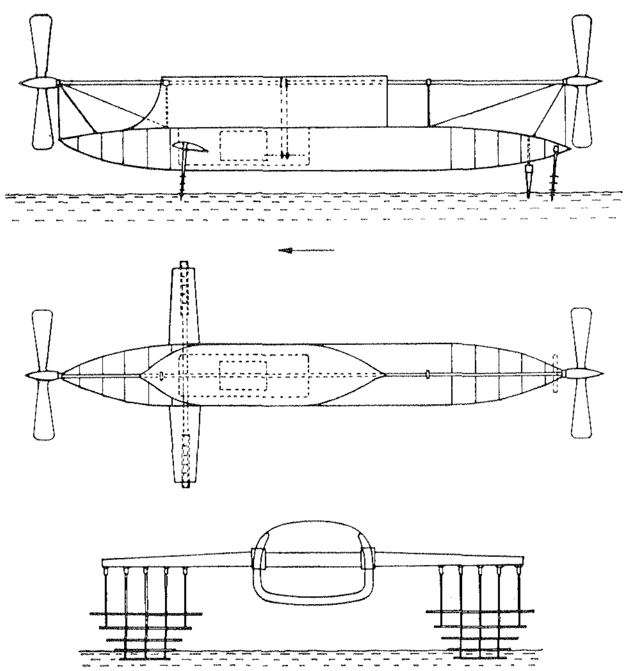
so that $P = 21S$ approximately.

Where P = all up weight of the craft
A = the total foil area in square metres
V = speed of craft in metres per second
S = horizontal reaction in kilograms

The last equation shows that the horizontal force required to propel the craft is as low as 1/21 of the total weight of the craft.

A document prepared by Forlanini states:

"The weight p that can be supported by a certain blade having a certain inclination is substantially proportional to the square of its speed (v^2). The resistance s of the blade during the travel of the machine, which is to be overcome by the propeller, is also substantially proportional to the square of the speed (v^2). The resistance of a number of superimposed submerged blades is therefore proportional to the number. If my machine travels at an increasing speed (v) the number of the supporting blades travelling below the surface of the water will decrease proportionally to the square of the speed (v^2). There is, therefore, an increase of the resistance



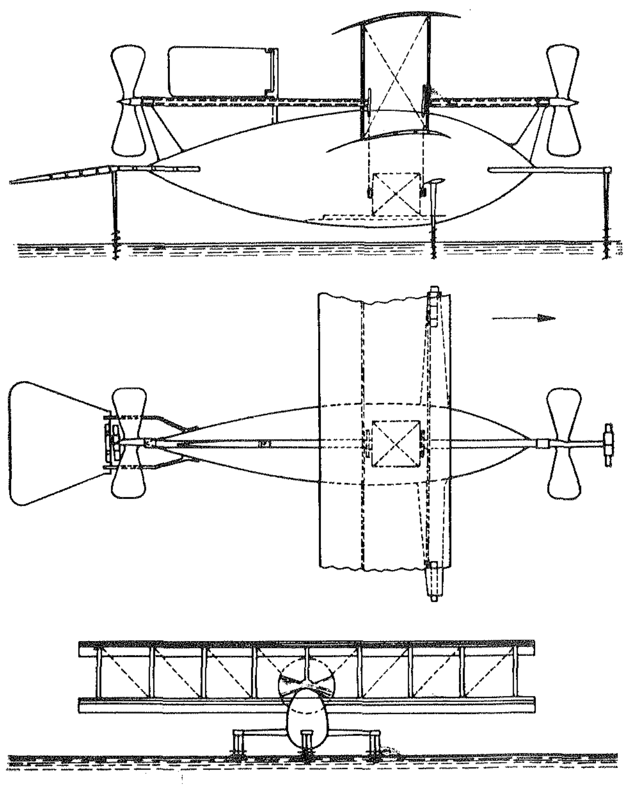


Figure 3. *Forlanini's craft No.* 3. Figure 4 (right). *Forlanini's proposals for incorporating foils with aircraft*

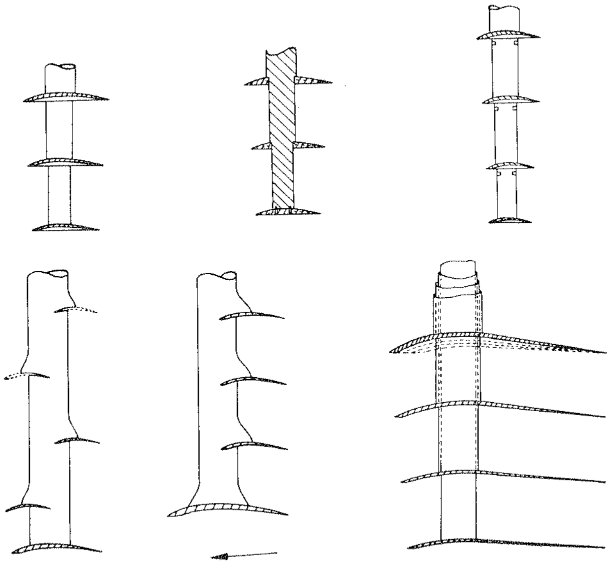


Figure 5. *Various methods of fixing foils to the carrier rods*

of the machine proportionally to v^2, on account of the increased resistance of the different blades and at the same time a decrease of the resistance of the machine also proportional to v^2, on account of the decreased number of submerged blades. It follows, therefore, that the resistance of the machine is independent of its speed, and that, furthermore, the energy required for propelling my machine is proportional to its speed. This conclusion is also applicable theoretically to other machines sustained more or less but never totally by the dynamic reaction of the water, but for such other machines the reality does not respond to the theory, because the surface emerging from the water with the increasing of v remains always very near to the water and therefore always more or less exposed to its resistance, this fact annulling the principal characteristic of such kind of apparatus that is to be exposed to a resistance s constant and independent from v. My apparatus on the contrary is provided with water-blades which are disposed at different levels in such a way that when, by the increasing of v, some of all of them become superfluous as supports of the apparatus and withdraw from the water, they get far away from the same and are entirely and continually out of contact therewith. My apparatus realizes therefore and for the first time, practically and effectually the above mentioned law on the constancy of the resistance independently of v.

It will readily be understood that the values p and s vary according to the depth to which the blade is submerged and they have their smallest measure when the blade just glides with its front edge over the surface of the water. The values are increased by 60% if the blade is what may be termed a deep blade, that is, if it is submerged to a depth about equal to its length, the length of the blade being in this case its dimension in the line of travel."

Fig. 3 illustrates a craft weighing approximately 2,650 lb. having a 60 horse-power engine and designed to operate at a speed of 56 miles per hour.

The craft is driven by contra-rotating, coaxial airscrews, one at each end of the craft.

Cowled rotatable beams carry the rods supporting varying length and width foils. The foils are located at a considerable sideways distance from the main body of the craft to ensure the best possible transverse equilibrium. The foils may be telescopically arranged on tubular legs enabling the distance between the foils to be varied.

Fig. 4 shows diagrammatically Forlanini's proposals for incorporating foils with aircraft. Many variations of the basic design were suggested by Forlanini and some of them can be seen in the illustrations forming part of his British Patent 7603/1905 and U.S.A. Patent 1,112,405.

On the 26th July 1907 Forlanini applied for further British and American patents, 17156/1907 and 1,024,067 respectively, relating to improved methods of fixing the foils to the carrier rods, the provision of "starting foils" which can be rendered inoperative at high speed and safety carrier rods.

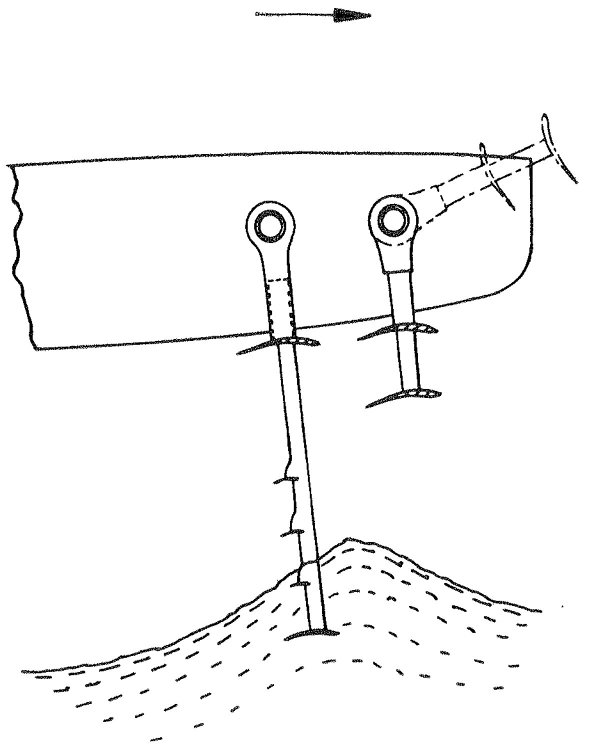
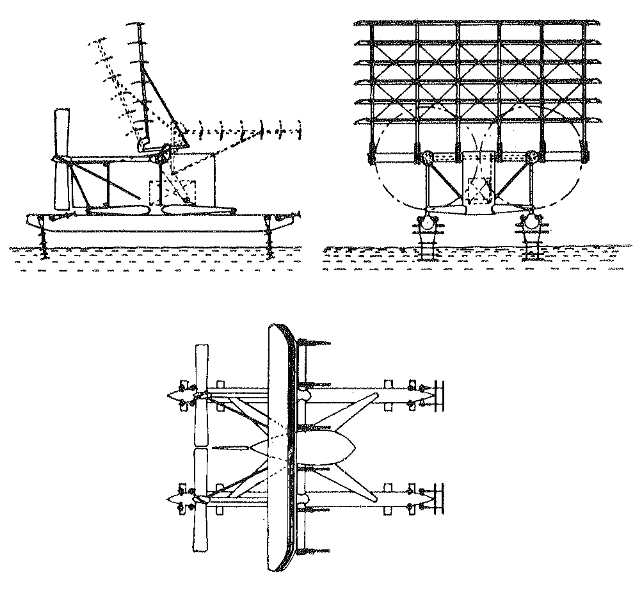


Figure 6. *Retractable "starting" foils patented by Forlanini*

Fig. 5 illustrates the various types of foil attachment and Fig. 6 shows a typical arrangement of retractable "starting foils". An attempt to combine the advantages of hydrofoil craft with aircraft is shown in Fig. 7. Forlanini states that the total weight of the craft shown should be approximately 1,100 lb. Starting foils carried by special rods formed from hard steel, of small flexibility and having a number of specially provided weak points or break points, so that a horizontal strain bearing on a foil would break the rod at some predetermined point and prevent undesirable damage to the craft, are incorporated. A multi-wing structure is arranged to fold to the horizontal position when the craft is to be used as a boat or on starting, and to move through an angle of approximately ninety degrees to a vertical position when the craft is to be used as a flying machine.

Figure 7. *Combined hydrofoil and aircraft with folding wing structure which folds horizontally when craft is used as boat*

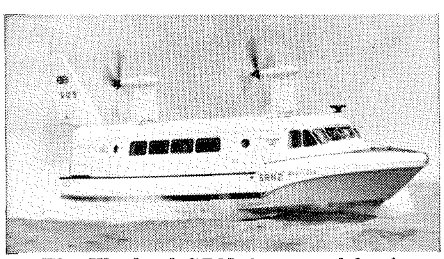


Bristol Siddeley power for Air Cushion Vehicles

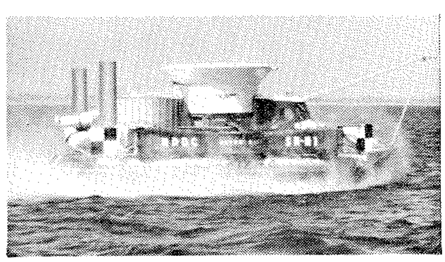
Bristol Siddeley gas turbines have been chosen for five air cushion vehicles, the Westland SRN 1 (Mks 3 & 4), the SRN 2, and the Vickers VA-1 and VA-3. These applications have given Bristol Siddeley unrivalled experience in the use of gas turbines for this type of vehicle.

With over 20 years experience in the production of gas turbines, and now manufacturing the widest range in the world, Bristol Siddeley are well equipped to meet the power requirements of this new form of transport.

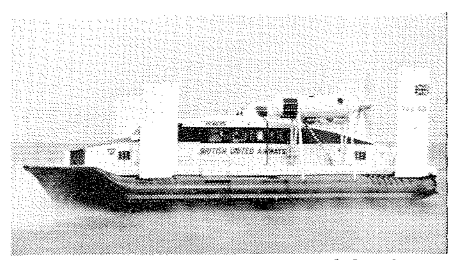
For further information, please write to: The Sales Manager, Power Division, Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.



The Westland SRN 2 powered by four Nimbus engines.



The Westland SRN 1 uses a Viper gas turbine.



The Vickers VA-3 is powered by four Turmo engines.

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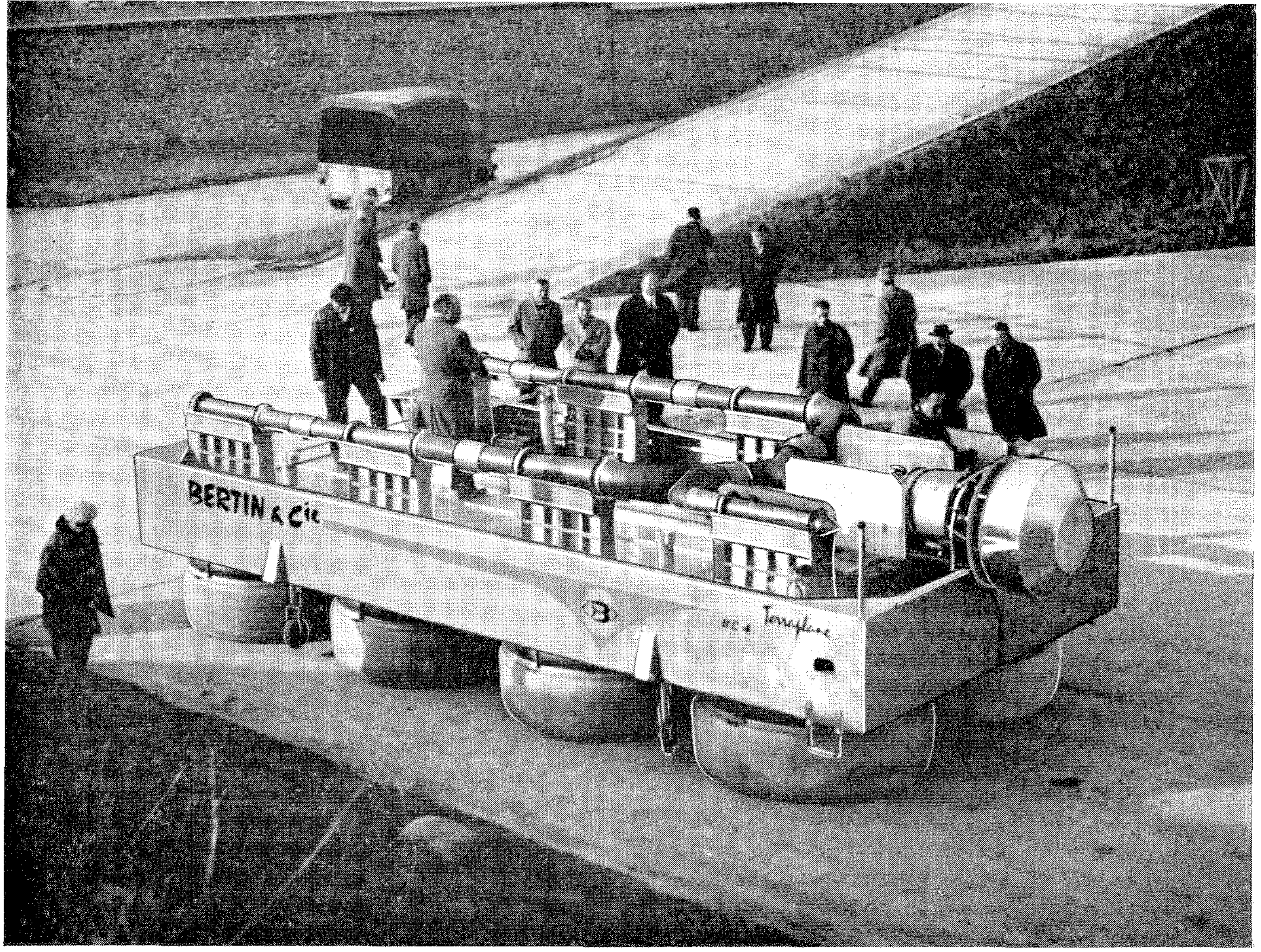


TERRAPLANE BC—4

THE Bertin Company's interest in air cushion vehicles dates back to early 1957. During 1955 this French company was engaged in studies utilizing small circular or eliptical annular jets for propulsion ducts and jet orifices. While measuring the efficiency and mass flow through annular jet injectors Bertin engineers established that the apparent pressure developed by a profile where inflow was obstructed could be several times greater than the impulse pressure of the jet and they applied this phenomenon to design a practical wheel-less vehicle.

Test apparatus quickly confirmed theory and resulted in the construction of the Terraplane BC-4 seen above which began operative trials in March 1962. The main platform or flotation chamber, 25 ft. 6 in. in length and 10 ft. 6 in. in width has been used to test various air cushion systems and to study the behaviour of flexible skirts when crossing obstacles.

The eight flexible skirts or air chambers are pivotally mounted to the underside of the main platform, each chamber being 5 ft. 1 in. in diameter and 1 ft. 9½ in. in height. The lower edge of each skirt is 1-1½ in. above the ground when the vehicle is operating.

A Turboméca Marboré II turbojet engine, weighing 345 lb. and giving 880 lb. static thrust is installed on the front of the platform. The jet efflux from the engine is delivered along two ducts, one on each side of the platform, and passes through special Bertin injectors to the eight individual flexible air chambers. The injectors increase the air mass flow by seven or eight times and at the same time reduce both the speed and temperature of the engine exhaust gases to a safety level. All-up laden weight of the vehicle is 7,710 lb. and the weight empty is 3,300 lb.

Directional control is obtained by tilting the entire group of flexible air chambers in the direction of travel. This is accomplished by a manual, hand operated, pilot's control. To turn the vehicle the front and rear air chambers are tilted in opposite directions by a manual, foot operated, pilot control. Other systems of control are at present being investigated.

One of the features claimed for the Bertin Terraplane BC-4 is the ease with which the vehicle passes over obstacles and especially when the obstacles are of a longitudinal dimension proportionate to the length of the platform. The flexible air chambers give way successively, the platform being supported by the remaining air chambers.

Independent pressure supply permits these air chambers to support momentarily an increase of pressure up to two or three times the normal value of the pressure load and this can be done with an almost negligible alteration in the general level of the platform. This ability of altering the pressure loading is one of the features of the vehicle.

The flexible skirts are frequently in contact with the ground during operation of the vehicle and skirt wear or damage may occur. Skirts manufactured from rubberised fabric are expendible items as are brakes on conventional vehicles and provided they are designed to be easily interchangeable they present no problems.

In September 1962 the Terraplane was delivered to the French military authorities for environmental tests. Considerable interest has been shown in the Bertin project by Sud-Aviation who acquired the option of a manufacturing licence in January 1961.

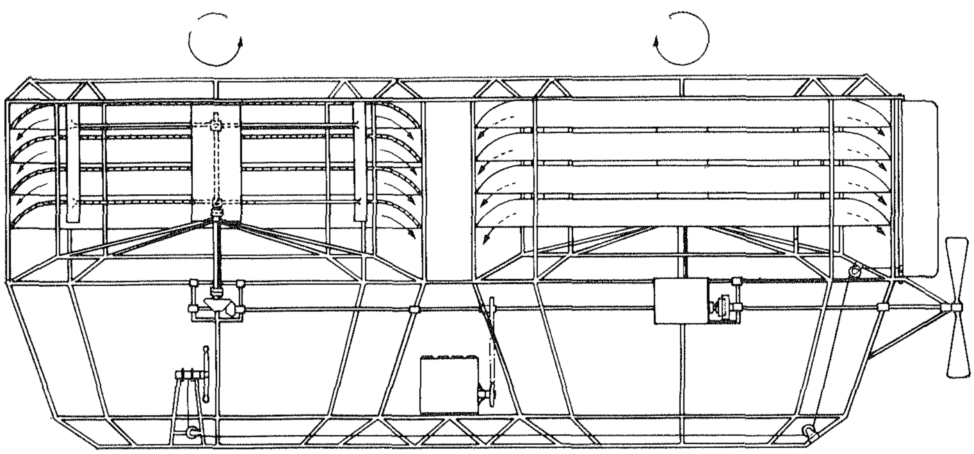


Figure 17. *This design by James R. Porter, an Englishman, marked the start of his interest in ground effect machines*

THE HISTORY OF AIR CUSHION VEHICLES
(Part II)

L. H. Hayward,
Group Patents Manager,
Westland Aircraft Limited

JAMES R. PORTER, an English engineer, now enters the story with a series of Patents dating from October, 1908. In British Patent 21216/1908 and U.S.A. 1016359 (Fig. 17) Porter suggested a heavier than air flying machine having a tubular framework carrying a large diameter engine driven fan to force air out through a series of superimposed downwardly turned radial planes. Air acts on the underside of the planes and is deflected downwards to lift the machine. To counterbalance torque, two such arrangements are connected in tandem, and forward propulsion is obtained from a normal propeller. Although not strictly a ground effect machine, this appears to be the start of Porter's interest in such machines. The machine was built and exhibited at an aeronautical exhibition in London during 1909. The fans were 5 ft. in diameter and driven via belts and pulleys by a 5 h.p. motor.

In March, 1909, Porter obtained British Patent 5391/1909. This discloses a method of obtaining horizontal motion by adjusting segments in the air reaction surfaces.

In 1910 a new design of machine was suggested using a large fan drawing in atmospheric air and delivering the air through ducting so that it issues in a downwardly direction to lift and support the machine in the air. Again segments may be used for directional control and as a refinement Porter suggested the use of swivelling air discharge nozzles. In this Specification Porter says that in some cases it would be preferable to enclose the top anulus over the fan and draw air through apertures provided on the underside.

It would appear that he had second thoughts concerning the air intake entry to the fan as his British Patent of Addition 10703/1911 states that the arrangement for sealing off the top of the fan does not in practice give the best results. He suggests now that the bottom orifice is completely closed off and air is only allowed to enter through the top central aperture. He states that by closing off the lower opening a much improved lifting effect is obtained. The results of Porter's early experiments are given in his book published in England during 1911 and the illustration now shown (Fig. 18) is taken from this publication.

The next development was the subject of British Patent 15735/1912 where he suggests a number of fixed guide blades for better distribution of the air to the fan from the ducts. One point of interest in this specification is that it refers to aeronautical machines, marine vessels or road vessels, and on the illustration shown (Fig. 19) a buoyancy chamber is provided.

Directional control still appears to have been a serious problem and in January, 1913, Porter obtained a further Patent disclosing pivoted flaps spaced around the outlet duct and being manually operable to control air discharge and, therefore, direction of travel, operation of the flaps tends to tilt the machine producing forward motion.

In March, 1913, Porter suggested a machine which falls within the annular jet classification. The underside is completely closed and is elliptical in form. The engine and other mechanisms are enclosed to prevent break-up of smooth flowing air and to attempt silencing. Probably the most important of Porter's contributions is that described in British Patent 975/1914. This suggested a design very similar in principle to some of the machines being produced today. As shown in the illustration (Fig. 20), air is drawn over a large curved surface by a vertically mounted engine driven fan and then forced through an annular duct. The outlet of the duct is provided with a large number of control segments which can be operated to direct the flow of air inwardly under a supporting surface or alternatively allow air to escape as required for directional control.

Further proposals of Porter's were made in 1915 which shows a machine capable of operating from water, the whole of the underside forming a built-in flotation chamber. If control segments are provided as described in the earlier patent, they are arranged to be drawn in and fit tightly to the sides of the flotation chamber when the machine is on the water.

A. U. ALCOCK 1912-1914 — AUSTRALIA

Probably the earliest "ground effect" man in Australia and one of the first practical men in this field was A. U. Alcock, formerly of Perth, Australia, but who retired to Devon, England, where he died recently. He was still doing a certain amount of work in his own workshop although in his 90s.

As an electrical and mechanical engineer working in Perth, Australia, early in the century, he built a working model of a "hovercraft" in 1912 and demonstrated it before the Press and Australian Government officials. The Australian *Sunday Times* of 1912 states that their reporter witnessed the demonstration and gives some details.

The model was simply a platform of wood 4 ft. x 4 ft. x 2 in. on which was mounted an electric motor driving a compressor and propeller. Air from the compressor was pumped beneath the platform, through a single orifice to provide a "cushion" on "levapad" principles. The propeller provided thrust to move the model and the inventor called this mode of travel "floating traction", probably a much better term than that of "hovercraft".

Provisional Patents were taken out in Australia in 1914, 14309/1914, but since the inventor received no backing these were not proceeded with. Other models of Alcock's were demonstrated at the Cricklewood Ice Rink in 1939.

THE WARNER STORY

The name of Douglas Kent Warner should be known to every "Hovercraft" engineer. He is head of the Warner Research Laboratories at Tamiama Trial, Sarasota, Florida.

During 1928 he carried out a considerable amount of research and experimental work on air cushioned boats of the sidewall type and tested an outboard powered, ram supported craft on Lake Compounce, Connecticut in 1929 (Fig. 21). He delivered one to the U.S. Navy Building in Washington for test. Both of these craft had a tendency of letting a wave sweep the air out from under them and so stopping the craft abruptly. Warner redesigned his original craft and in 1930 drove it at the Middleton races on the Connecticut river.

U.S. Patent 1819216 shows that this craft had sidewalls or runners depending from airtight buoyancy chambers, spring-loaded flaps were fitted on the front and rear of

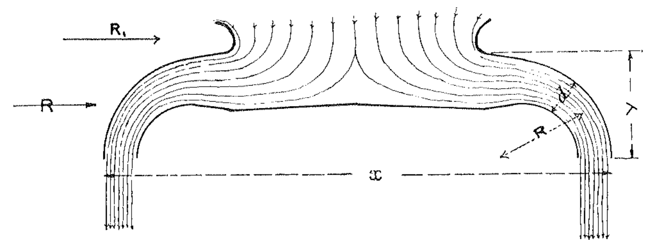


Figure 18. *One of the illustrations from a book written by Porter in 1911. It shows how by closing off the lower opening an improved lifting effect is obtained*

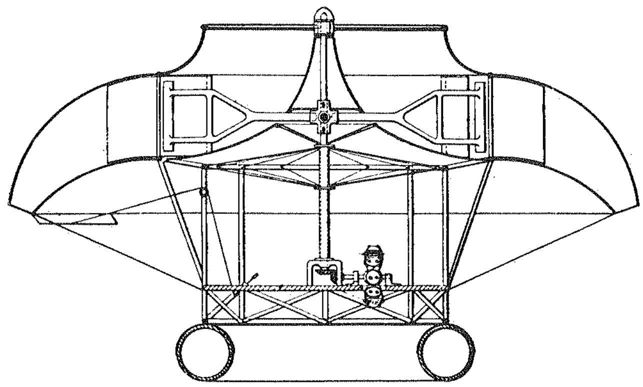


Figure 19. *In this patent of 1912 Porter suggested the use of fixed guide blades for better air distribution*

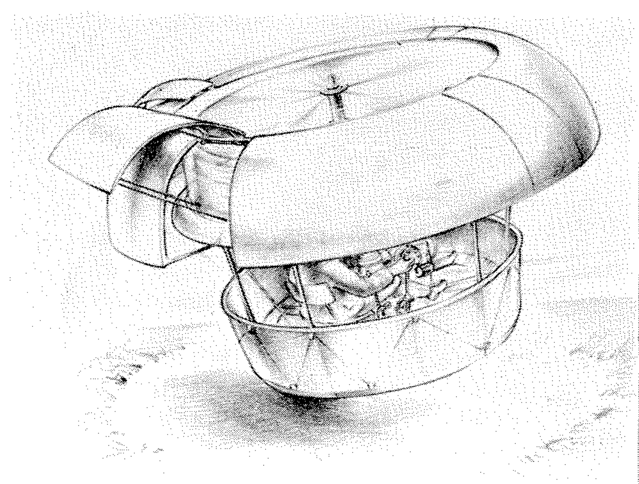
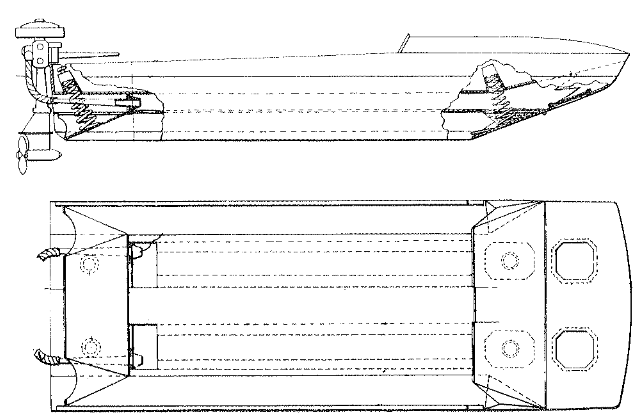


Figure 20. *Control segments for directional control were features of the proposal by Porter in 1915*

Figure 21. *Outboard ram supported craft tested by Douglas Kent Warner in 1929*



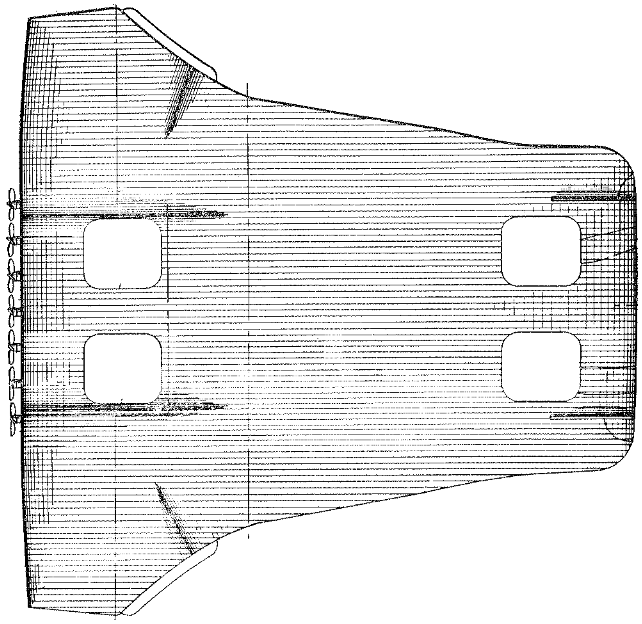


Figure 22. *Design for a ram wing skimming craft patented by Warner in* 1939

the craft acting as non-return valves for air trapped beneath it at above ambient pressure.

The rear flap could be adjusted to sea conditions prevailing. Exhaust gases were used to help lift the boat from the water and a water propeller provided forward motion. As the boat skimmed the waves the ram air pressure built up and the boat rose on an air cushion. The front and rear flaps were urged downwards by a spring mechanism to keep contact with the water and so maintain a pressure cushion. At the Middletown races this craft with a canvas tail flap weighted with steel balls was soon in trouble and so, too, was its inventor and pilot. The steel balls quickly wore through the canvas tail flap due to water friction and after rounding half the course it suddenly rose fifteen feet in the air and in returning to the water in a tail spin threw Warner out. This does not seem to have damped Warner's enthusiasm and by late 1930 he had designed and patented another sidewall cushion boat. But this time air propulsion was used in place of water screws. This second boat is shown in U.S. Patent 1855076. The air enters cylinders depressing the pistons and acting on the skids which raise the forward end of the boat as it gathers speed, ram air is forced into contact with the inclined bottom of the hull at the bow, which adds to the lift of the water skids and reduces the loading on the pneumatic rams. The motion of the pneumatic rams gives more uniform lifting of the boat in varying sea conditions. The ram air escapes rearwardly.

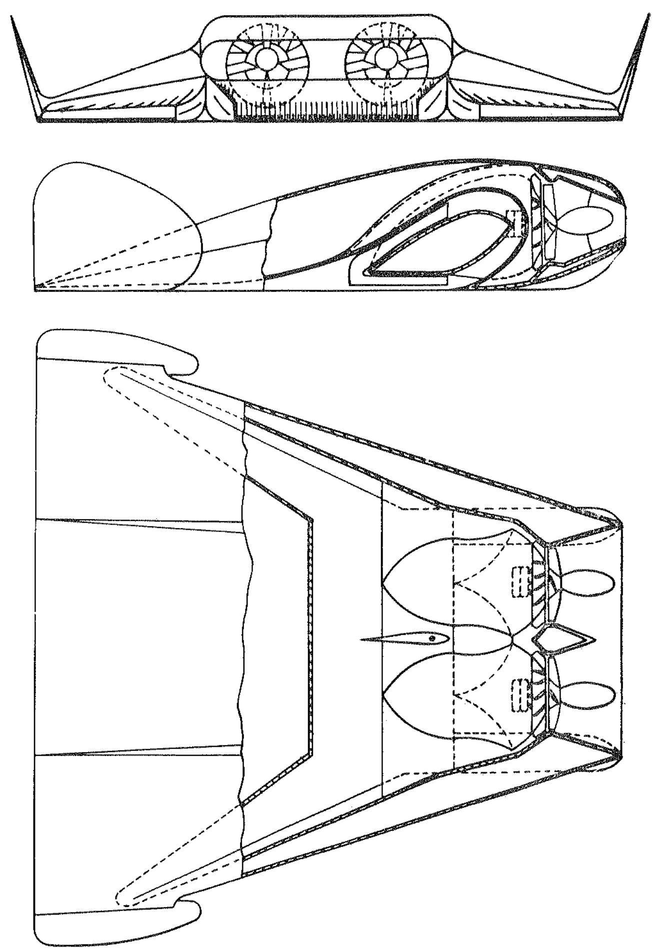
It is not known whether a craft was built of this design but we do know that Warner's invention in this field of activity turned to ram wing skimming craft. His first ram wing machine was of most unusual design as the idea of a large air cushion craft using waterscrews and hydrofoils is being considered as tomorrow's solution to some of the more pressing problems of stability in Hovercraft.

His first machine patented in January, 1939 (Fig. 22), U.S. 2277620, shows a wide area flying wing with seven tractor propellers along the leading edge and a pair of downwardly projecting stubwings carrying water screws. The stubwings also acted as hydroplane surfaces. One unusual feature of this design is a power system whereby the heat energy extracted by the water coolant for the main engines was used to drive the water propellers in a closed circuit system.

By May, 1940, Warner had designed and patented the first of a long line of skimming craft or pressure planes, as he sometimes called them. U.S. 2365676 shows one of his machines.

U.S. 2364677 (Fig. 23) shows a ram wing of a Mach 2 aircraft. On starting the engines, air is compressed within the pressure chamber beneath the aircraft which raises it from the ground or water. As soon as the craft is clear and supported on its air cushion, it is free to make a skimming flight and on obtaining high speed it can climb above ground effect to altitude. During skimming flight back pressure in the pressure chamber will cause some of the air to be forced back up over the centre aerofoil section and down again rearwards to be speeded up by the jet stream issuing beneath it. Figs. 24 and 25 show scale models built by Warner. This design is covered by U.S. Patent 2390859 (Fig. 26). Warner has had issued to him a large number of patents relating to ground effect machines and the illustrations shown (Figs. 27 and 28) indicate the considerable research and development which he has carried out.

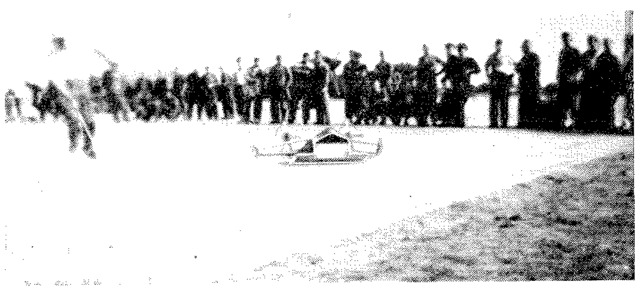
Figure 23. *Mach* 2 *aircraft with a ram wing proposed by Warner*



Another pioneer in the field of ground effect machinese was T. J. Kaario of Finland. He built and tested his first ground effect machine in 1935 (Fig. 29) — first as a glider and later powered with a 16 hp engine. The machine was 6 ft. by 8 ft. and attained a speed of 12 knots over ice on its first flight in late 1935. This machine was the subject of Finnish Patent 18630 granted to Kaario in 1935.

The craft shown in Fig. 30 made a considerable number of flights during 1935-36.

Finnish Patent 26122, of 1949, was a development of the earlier machines (Fig. 31). This machine was fitted with a 20 hp engine and made several controlled free flights towards the end of 1949. It is known to have hovered with four men on board, and tests were also made over the water. It is known that a 10 ft. craft powered with a Volkswagen engine has recently been built but results of tests are not known.



Figures 24 and 25. *Scale models used by Warner to demonstrate ram wing proposals*

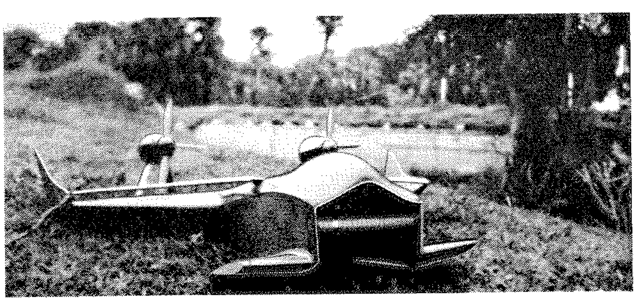
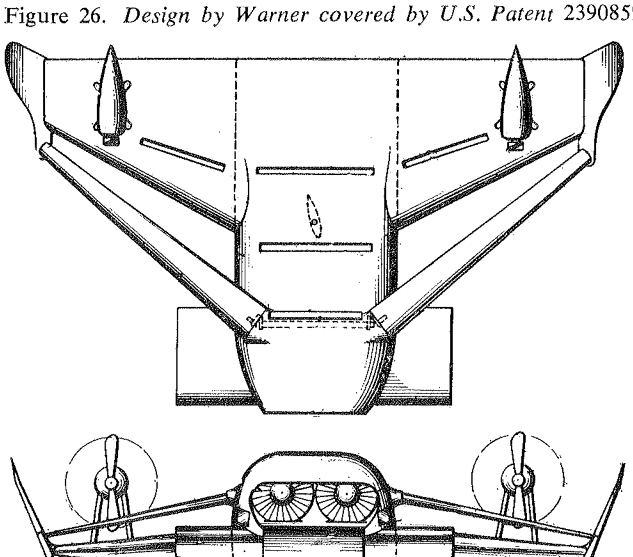
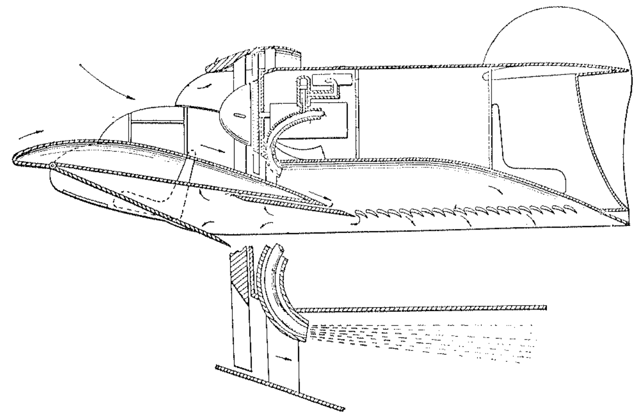


Figure 26. *Design by Warner covered by U.S. Patent* 2390859





Figures 27 and 28. *Two more of Warner's designs indicating the extent of his research*

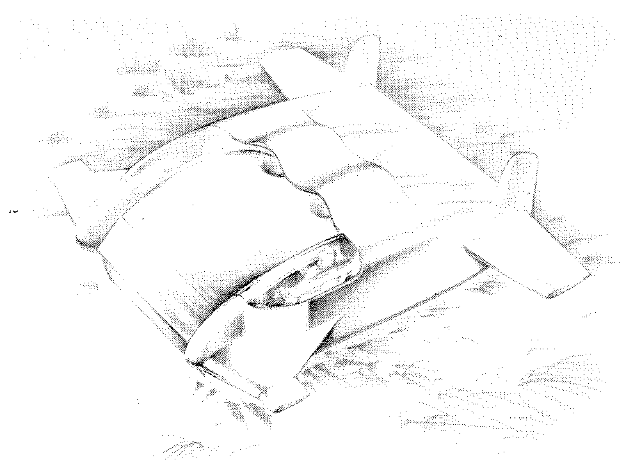


Figure 29. *Kaario's first ground effect machine, built in Finland in* 1935. *It attained a speed of* 12 *knots with a* 16 *hp engine*

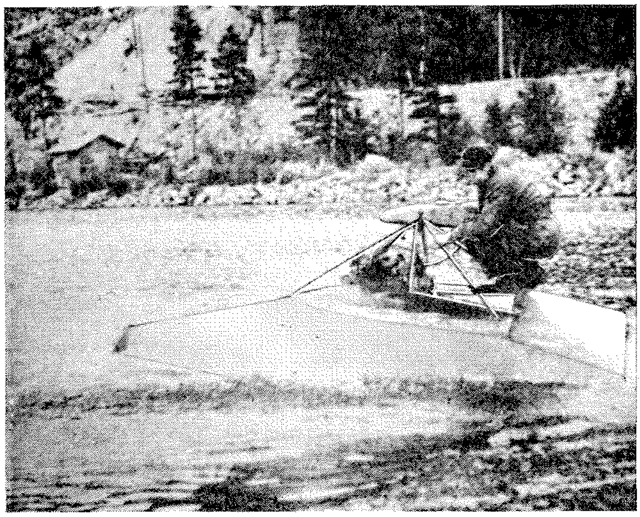


Figure 30. *Craft tested extensively by Kaario during* 1935-6

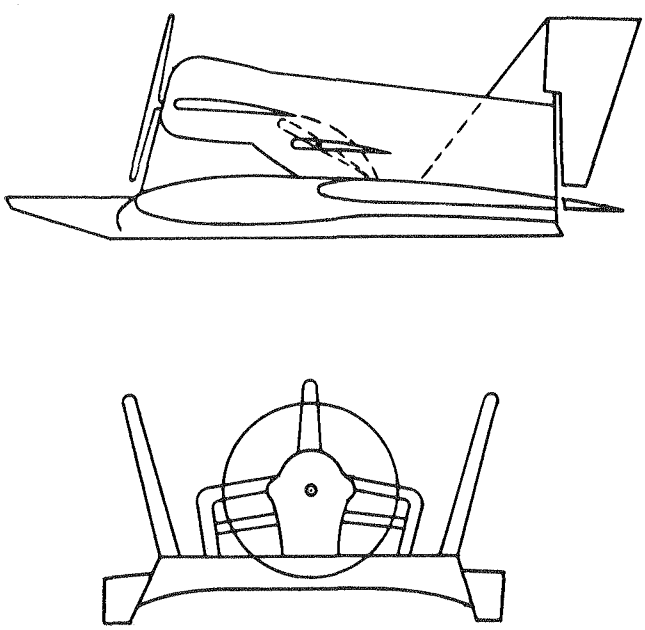


Figure 31. *A development of Kaario's earlier machines, this craft made its first flight towards the end of* 1949

The story of Christopher Cockerell, his experimental models and his fight to interest a manufacturer in his design proposals is too well known to need repetition here. The first British Patent issued to Cockerell No. 854211, dated December, 1955 (Fig. 32), illustrates his original proposals. An artist's impression of an early model is shown in Fig. 33. This patent which covers the peripheral jet concept with inturned jets has resulted in the rebirth of a new industry in G.B. and the formation of Hovercraft Development Ltd., who now own all patents and applications pending to Cockerell.

The Saunders-Roe Division of Westland Aircraft, Vickers (South Marston) Ltd., and Denny Bros. of Dumbarton, have all produced machines in collaboration with H.D.L.

At least one man was thinking on the same lines as Cockerell at the same time and filed a Provisional Application for a Patent in Brazil during August, 1955. The specification of Renalto Alves De Lima shows a circular vehicle provided with counter rotating fans which draw air in from the upper edge of the craft, compress it within a plenum chamber and then discharge it through a peripheral jet to create a "column of air which reacted against confinement", and on which the vehicle rode 15-20 cms. above the ground. (Fig. 34.) Propulsion, he said, could be by an outboard motorised propeller or a jet emanating from the machine itself.

Quoting from de Lima's Specification it is stated that: "The craft flied skimming the surface, always following the undulations of the road, rising and descending, always airborne and away from the ground, with no assistance from the pilot; this work is performed by the craft itself which skims over the obstacle and down again just as if it were travelling on wheels. Thus on climbing a slope the vehicle tilts backwards, and going down it tilts forwards.

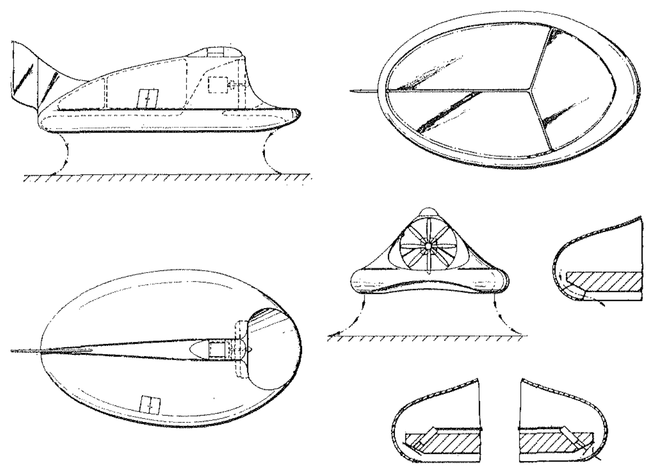
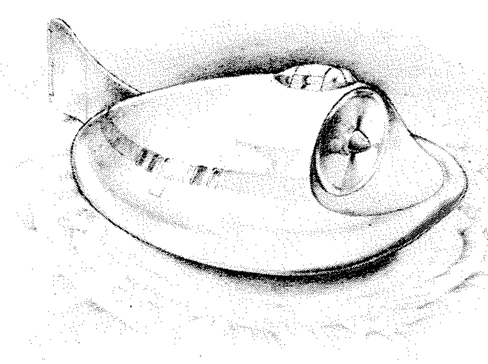


Figure 32. *Christopher Cockerell's original Hovercraft proposal*

Figure 33. *An impression of an early model of Christopher Cockerell's original design*



"This column of air does, however, maintain the craft airborne with less power than an ordinary aircraft would require. Steering is effected by rudder and controllable blades or vanes which deflect the air discharge".

De Lima further stated that the craft may be built in various shapes; round, triangular, etc., and may be supported by one or more columns of air or even two parallel columns. (Fig. 35) forms part of his patent application.

In another embodiment of his invention he stated that an aeroplane could use an air cushion in place of conventional landing gear, thus dispensing with expensive runways, etc. (Fig. 36.)

The drawings in de Lima's specification are crude and his technical description is not that of an engineer, but there is no doubt that he had the basic idea of a ground effect vehicle using a peripheral jet system.

The difference between de Lima's idea and Cockerell seems to be that his (de Lima's) jet discharges vertically downwards.

Unfortunately, de Lima could not raise a spark of enthusiasm in anybody in his country and was not prepared to go to the expense of completing his Patent. Consequently, his disclosure has no effect upon subsequently issued patents.

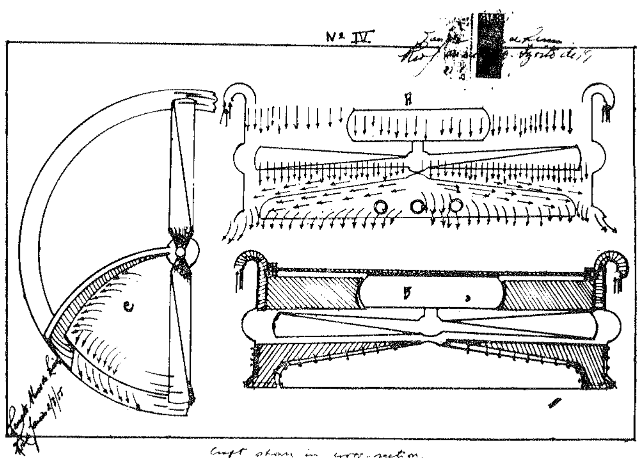
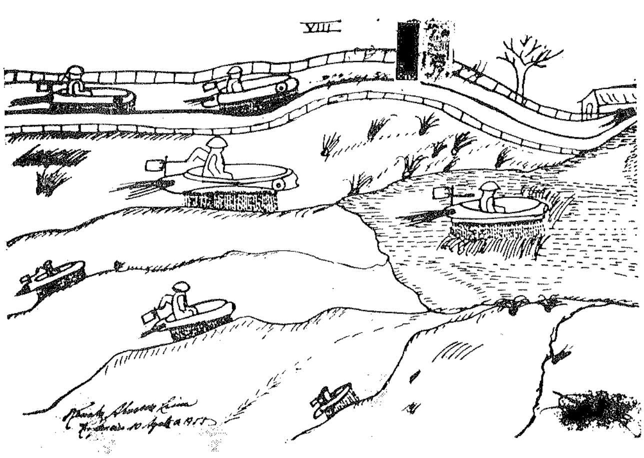


Figure 34. *A provisional application for a patent for this machine was filed by Renalto Alves De Lima in Brazil in August* 1955

Figure 35. *De Lima stated his craft could be built in various shapes and be supported by one or more columns of air or even by two parallel columns*



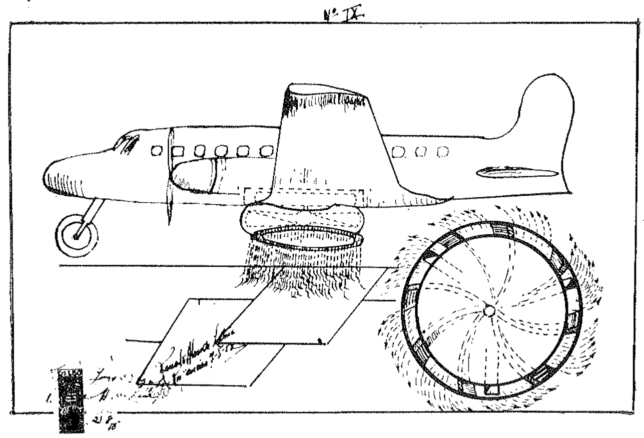


Figure 36. *One of De Lima's proposals was that his air cushion invention should be used on an aircraft in place of a conventional landing gear*

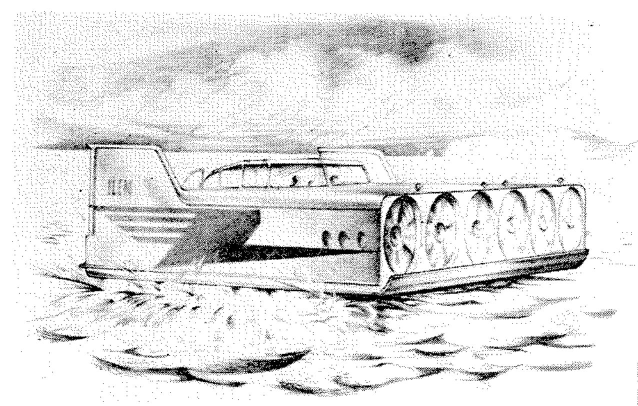


Figure 37. *Carl Weiland constructed two of these machines to demonstrate the labyrinth seal system*

The only Swiss project is that of Carl Weiland who was an engineer with the Federal Aircraft Organization at Emmen, Switzerland, and is now in the United States.

Weiland was an exponent of the labyrinth seal system and it is known that he has constructed two machines of the configuration shown in (Fig. 37). This machine was approximately 35 ft. x 30 ft. and had six forward facing air intakes each housing a fan. Two engines developing 700 h.p. were used and the machine is reported to have reached a speed of 60 m.p.h. over water on Lake Zurich. The first of these craft sank through some unexplained accident during a heavy storm and the second one has now been acquired by the United States Navy for research work. It is not known whether this second machine is the rebuilt salvaged machine or one of entirely new construction.

(Fig. 38) shows the labyrinth seal principle used by Carl Weiland and patented in October, 1957. Air drawn in from leading edge intakes is compressed in annular compartments separated by steps or labyrinths and as it escapes from the inner compartment it is drawn up by a fan in the next compartment and turned back upon itself.

This method of recirculating the air is an attempt to reduce engine power requirements.

Further interesting projects have been developed by A. V. Roe in Canada, known as the Avro-Car and many

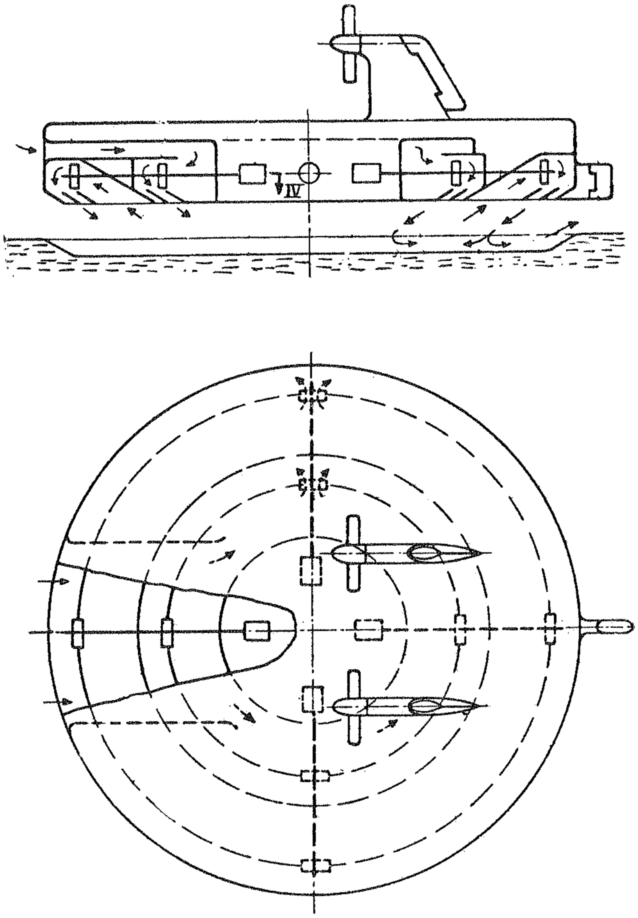


Figure 38. *Carl Weiland's labyrinth seal principle patented in October* 1957

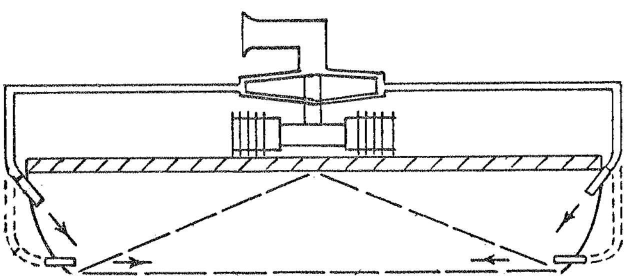


Figure 39. *C. H. Latimer-Needham's design for a flexible skirt*

patents have been issued or are in the process of issuing covering the engineering of this machine.

The Canadian machine is a combination of peripheral jet and lentiform wing. Work commenced in 1955 but has recently been abandoned.

An invention which is proving to be of considerable importance was made by an Englishman, C. H. Latimer-Needham, during 1958. This invention is covered by British Patent 860781 (Fig. 39) and relates to the provision of flexible skirts which can be adapted to any form of ground effect machine to maintain the air cushion at a considerable depth, thereby giving a greater clearance height in operation. This patent has been acquired by Westland Aircraft Ltd.

The first machine produced in France has been named the Terraplane by its inventor and manufacturer, M. Bertin (Fig. 40). A rectangular platform 24 ft. long, 11 ft. wide, houses eight small units which provide the air cushion. Tiltable, flexible skirts 22 in. in depth and 5 ft. in diameter are fitted to each of the eight units. This craft has an unladen weight of 3,300 lb. and can carry a load of 3,300 lb. A turbo jet engine developing 880 lb. thrust feeds air through eight large bore tubes. The action of the skirts is shown in (Fig. 41).

Great interest is being shown by the French Army.

The platform of the machine is at present being filled with an expanded plastic material to provide buoyancy and enable water trials to take place.

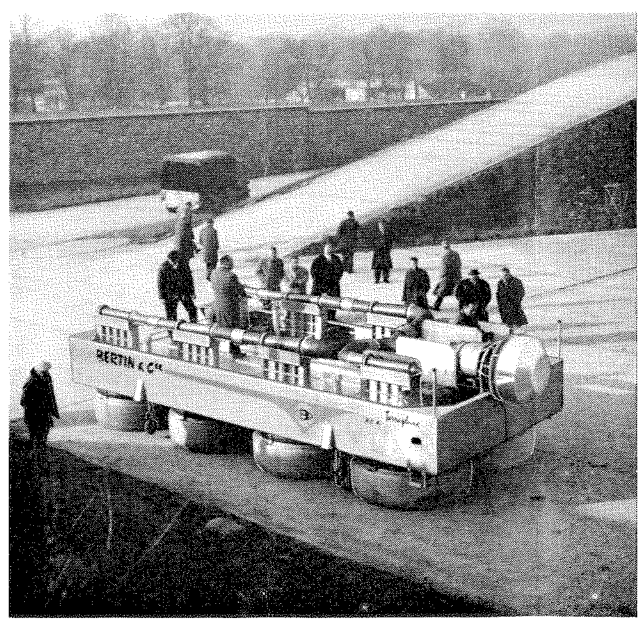
CERN

A number of industrial uses have been put forward which utilise an air cushion. One such proposal has been made by the European Organization for Nuclear Research and in this case a load of 30 tons was moved on four discs of 500 mm. diameter, the friction coefficient on a smooth concrete floor was about 1% whereas the co-efficient for a smooth steel plate on the same floor for the same specific pressure amounts to about 30% (Figs. 42 and 43).

The air cushion system can be built as an integral part of a machine or alternatively they can be adapted to be fitted under the apparatus which needs to be moved.

This work was originally started in early 1957 and developments are still proceeding.

Figure 40. *The Bertin Terraplane*



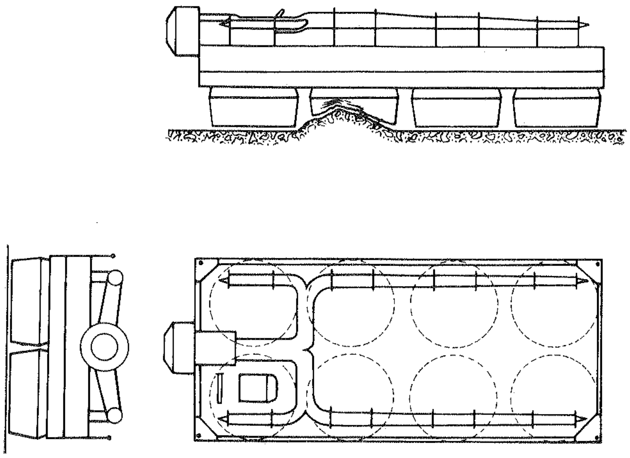
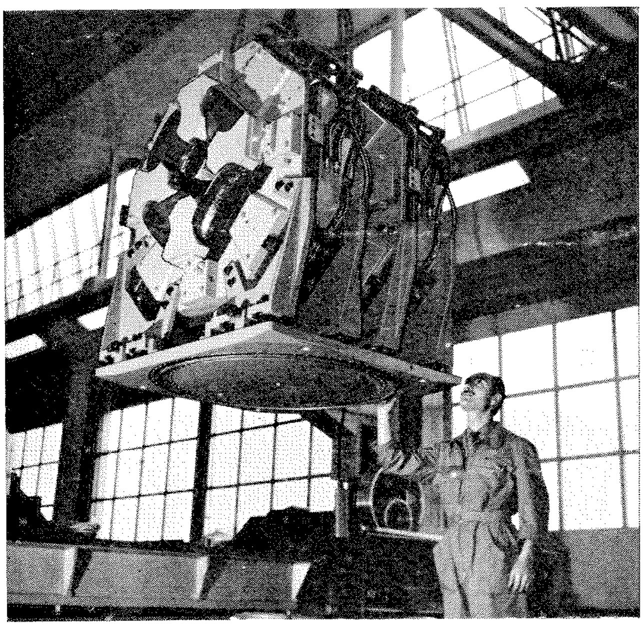


Figure 41. *Skirt action on the Bertin Terraplane*



Figures 42 and 43. *Industrial use of the air cushion is illustrated by these applicators designed by the European organisation of Nuclear Research for moving heavy components by hand.*

CONTROL SYSTEMS ON THE DENISON

First Hydrofoil With An Aircraft-type Flight-Deck

THIS spring the U.S. Maritime Administration's "first generation" hydrofoil, the 95-ton Denison, is due to go into service with Grace Line between Port Everglades and the Bahamas.

A description of the Denison's control system was given in September by J. Craig Schroeder, Project Engineer, Grumman Aircraft Engineering Corporation before the U.S. National Meeting on Hydrofoils and Air Cushion Vehicles.

All systems — propulsion, piping and electrical — are designed for remote operation and monitoring from a single area in the pilot house. The engine throttles and flight controls along with key monitoring instruments and a warning system are located within easy reach of the captain and first mate. Remaining system management and surveillance instrumentation for the propulsion units are located at the engineer's console, where there is a master warning system and a schematic control panel.

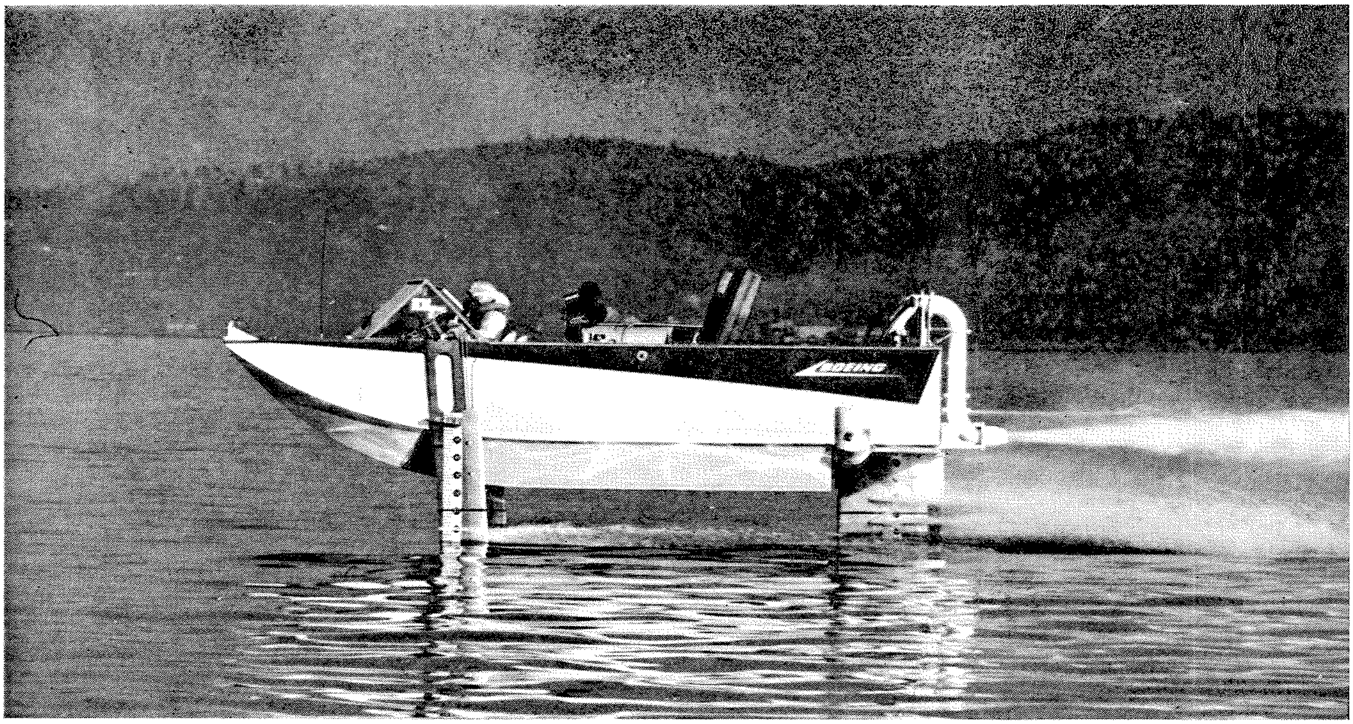
The control systems on the Denison include retraction and locking of foils, steering, flap and aft foil control and engine controls. In general mechanical linkages have been used wherever possible with hydraulic cylinders actuating the powered portions of the various systems. This arrangement was selected since it provides the maximum in reliability for key functions.

There are two separate hydraulic systems aboard the craft, a displacement system and a foil borne system. The foil borne system, a tandem design with dual pumps, dual reservoirs and dual actuators, controls the steering, main foil flaps and the aft foil incidence. The actuators which control the flaps and aft foil have several sources of inputs. When in its automatic mode the stability augmentation system which senses leave acceleration through an accelerometer located at the craft C.G., pitch and roll through a vertical gyro and yaw rate through a rate gyro feeds signals to these actuators through their servo valves. When the augmentation system is in its manual mode switches in the pilothouse allow the captain to manually change the craft attitude with signals to these same servo valve inputs.

During the design phase small motor driven screw jacks, which position the hydraulic actuator pilot valve and hence the actuator and control surface were added for increased reliability. Since the craft can be flown with all control surfaces at some fixed position this method of setting the surfaces insures that the craft can be flown if the more sophisticated augmentation system is inoperative.

The steering system is a cable and push rod system aft to a tandem hydraulic actuator which controls the position of vertical rudder flaps on the aft strut. During coordinated turns, the roll of the craft is controlled by signals from the stability augmentation system to the main foil flap actuators.

The displacement hydraulic system consists of a single pump driven by the displacement propulsion transmission. It provides power for services such as foil retraction, foil locks, and miscellaneous services such as hydraulic motors, hydraulic brakes and several minor cylinders. This system as well as the foilborne system operates at 3,000 psi and is composed of aircraft components.



Pump Jet, Boeing's new 20 ft. research hydrofoil, is designed to test water-jet propulsion and submerged hydrofoil systems

WATER-JET HYDROFOIL

BOEING has recently completed a 20 ft. hydrofoil for research powered by a water-jet propulsion system. The craft has fully submerged stainless steel foils and is designed to reach speeds in the region of 45 knots.

Apart from being the first of the company's hydrofoils to "fly", the craft also has the distinction of being the first anywhere in which a pump jet has been combined with a fully-submerged foil system.

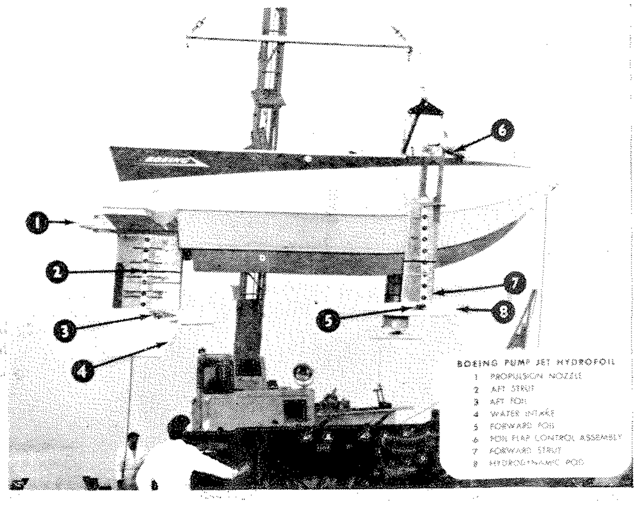
A scoop built into the craft foil strut takes water into the craft and a high-speed centrifugal pump pours it out in a 30 ft. stream through an aft nozzle.

The foils, similar in basic design to those on the FRESH-1 and the PC(H), incorporate movable control surfaces operated by a Boeing electronic system. The pitch of the foils can be changed during operation compounding the action of the movable control surfaces.

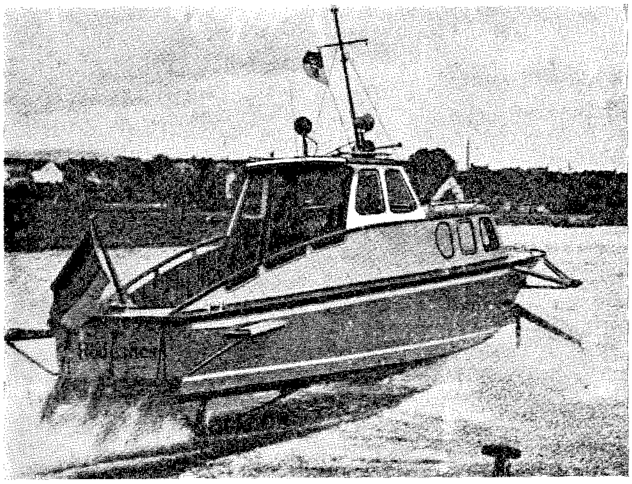
Constructed in plywood the hull is of a modified catamaran configuration to raise the boat as much as possible before the foils take over and to provide good landing characteristics. Hull, foils and most of the other systems have been designed and built by Boeing, including the engine — a 475 shp Boeing 502 gas turbine. This turns a centrifugal pump, manufactured by Pacific Pumps Inc., Huntingdon Park, California, which develops more than 2,000 lb. of thrust and pours 3,500 galls. per min. of water through a 4 in. nozzle.

Data

Weight, 2-5 tons; length, 20 ft. (6.09 m); beam, 8 ft. (2.43 m); speed, 45 mph (72 km/h). Draught, hullborne, 6 ft. (1.82 m); foilborne, 8 in. (20 cm) to almost 2½ ft. (76 cm).



Some of the more unusual characteristics of the craft are seen in this keyed photograph



One of the three Supramar PT 3s *operated on the Rhine by the Hessian waterpolice*

HYDROFOILS HELP HESSIAN WATERPOLICE

Polizei Oberrat Wilhelm Schäffer Weisbaden Kastel

TWO of the main factors that led to the introduction of hydrofoils in police service on the Hesse were the big increase in the volume of commercial and pleasure traffic and a general increase in the speed of watercraft. While the latest high-powered planing boats have the necessary manoeuvrability and speed for police use, the wash they create at medium and high speeds causes considerable inconvenience and can endanger small craft.

As a result their speed can only be of occasional value if danger and inconvenience are to be avoided.

At the same time the normal types of planing craft seldom possess the stability needed for police boats, so other, more suitable types, had to be found. Among the types examined was the hydrofoil.

After thoroughly testing the various hydrofoils available, it was decided that those employing the Schertel-Sachsenburg system seemed the best for our conditions.

The first three years of practical use with the first of the police hydrofoils proved that its design was fully up to expectations. It could be navigated at top speed in regions dense with ships, sailing craft, small motor boats and houseboats without endangering them. In narrow waters or canals, even at top speed, less wash was caused to affect banks and riverside structures than by slow or medium speed displacement craft.

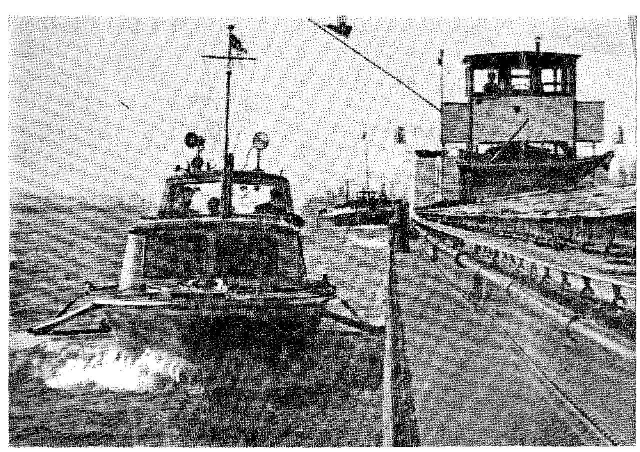
Foilborne, or hullborne, the biggest waves and currents caused by high tides or storms on the Rhine could be coped with quite safely. Landing-on could be achieved with ships in motion without difficulty, even when the craft concerned were towed barges lying in the wake of the considerable waves created by their tug-boats.

An interesting point noticed early on is that in the last phase of landing the hydrofoil heels over much less than a displacement boat. Another advantage is that other craft can be overtaken in narrow waters at a distance of only one or two metres without the wake impeding their course.

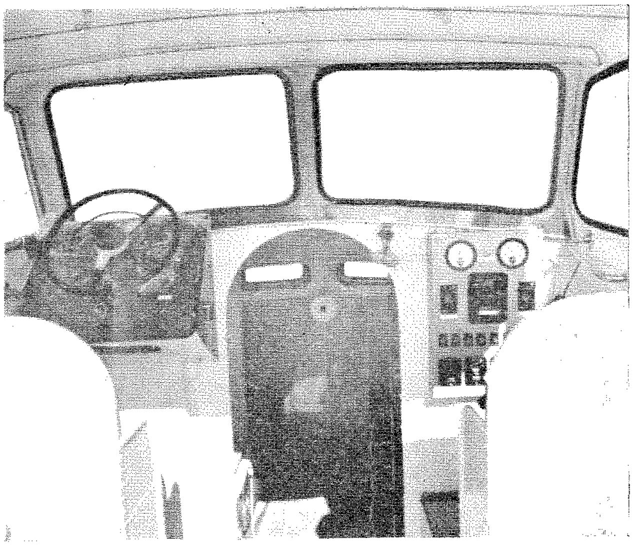
No special knowledge is needed to drive the hydrofoil. It can be operated by any reliable driver after a few practice rides. The best way to steer the craft is from a fixed seat, as in a car. Putting the craft to sea and getting foilborne takes only a short time; and stopping the craft — even from top speed — is also a brief operation. After throttling the fuel it can be brought to a stop in only two to four boat lengths because of the tremendous resistance once the craft dips into the water. The braking effect on the crew as it is pulled up from top speed is similar to that of a sharply braked car.

Driftwood — even of great strength — has not so far caused any damage to the foils. However, it can cause damage to the screws, because there is no bow wave to reject it. Because of this on the second craft the screws were sited behind the aft foil. On the first craft they lie in front of the foils without any protection. Only rarely has drifting material hindered the craft. On these occasions it has caught on one of the foils and it has resulted in slight loss of speed or a slight heeling over. On all occasions it has been cleared by stopping and reversing aft.

At times when medium and heavier ice drifts occur the craft are not used.



Landing-on from the waterpolice hydrofoils can be achieved with ships in motion without difficulty



The cabin of a standard Supramar PT 3

Foilborne the boat responds quickly to the rudder at all speeds. No more strength is required to move the rudder than that on a displacement craft. Hullborne the craft is as manoeuvrable as a displacement craft except at its lowest speed in currentless water when its response is somewhat slower.

Construction

The three hydrofoils in service are all Supramar design. The first was built at the Deggendorf/Donan shipyard and the second and third at the Bausch shipyard in Cologne.

The hull is constructed with a combination of long and square plates. For the external plates and bulkhead AL — Mg 5 Perulamium 5 a seawater-resistant alloy was used. In the interior AL — Mg — Si, another corrosion resistant alloy was used. In the front of the cabin is a strong bulkhead to which the bow is attached; this serves at the same time as a collision bulkhead.

The hydrofoil's hull and the foils have been specially designed for high-speed, seaworthiness and manoeuvrability. The foils and their supporting struts have been arranged in such a way as to simplify servicing and replacement. The angle of the forward foil is easy to alter during the voyage to give the best performance.

The rudder, activated through a hand steering wheel from the cabin, is sited immediately aft of the screw in order to obtain the maximum rudder reaction at slow speeds. The foremost part of the hull houses the anchor chain and is separated from the remainder of the craft by a watertight bulkhead. Behind this is the cabin with two upholstered benches, which can be made up into bunks, and a folding table.

Adjoining this is a galley area on the port side and a water closet on the starboard side. The aft of the cabin is closed by a bulkhead fitted with a door. Two fuel tanks each of approximately 100 litres, lie aft.

To protect the foils, which protrude approximately 25-30 cm. from the side of the craft, shock absorbers with castors at their extremities are fitted to the broadside.

The foils are made of specially strengthened corrosion-resistant steel and at their weakest point can stand a pressure of 80 tons. The bow foil can be raised hydraulically to the front to facilitate landing on shallow banks.

As the speed at which the boat can start foilborne operation is greatly influenced by the all-up weight, a motor of high output and light weight was necessary. At the time of the construction of the first craft no suitable diesel engine was available and the craft was therefore fitted with a petrol engine — a Mercedes-Benz M. 118. It provided 150 hp at a very low weight and 5,000 U/min. General overhauling was given after every 2,500-3,000 working hours — a normal period for engines of this type.

Diesel engines were installed into the second craft to reduce the fuel cost. The engines were Ford A. Dbs of 120 hp.

The most economical cruising speed of the craft is approximately 45 Km/hr; top speed is 60 Km/hr. With a full tank and 4-8 officials they have a radius of action of approximately 300 km. The normal number of a patrol on a boat is two to three. The craft carry loudhailers and VHF radio.

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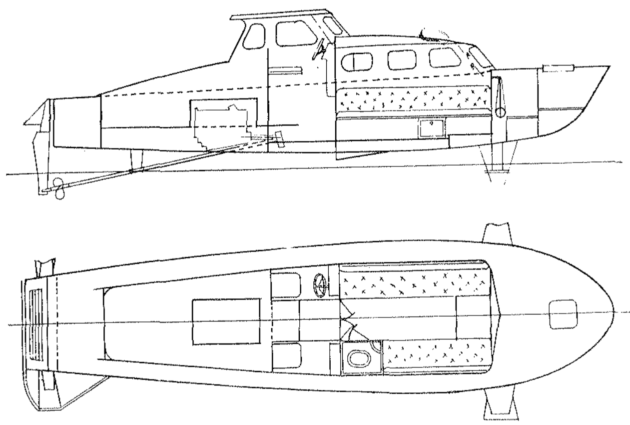

Side and plan views of a standard PT 3 *showing a typical cabin layout*